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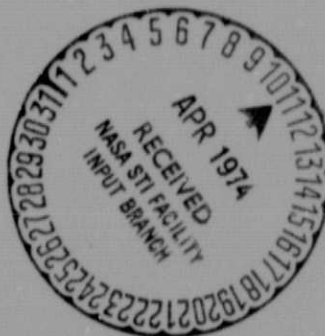
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INTERNAL FRICTION PEAKS OBSERVED IN EXPLOSIVELY-DEFORMED POLYCRYSTALLINE Mo, Nb, AND Cu

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and J. de Fouquet
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Cleveland, Ohio
January, 1974

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Explosive deformation (50 kbar range) induced, in Cu, Mo and Nb, internal friction peaks identical to those observed after large normal deformation.

The variation of the peaks with pressure for Mo and Nb lead to an explanation of these processes in terms of double kink generation in screw and edge dislocations.

INTRODUCTION

Intern ' friction peaks associated with dislocations have been previously investigated in molybdenum and niobium (refs. 1, 2, and 3). Their characteristics were determined largely by experiments on the amplitude independent damping for polycrystals deformed at slow rates, in both the elastic and plastic ranges, at various temperatures.

The present investigation was undertaken to study high velocity deformation effects on the internal friction spectrum.

Polycrystalline copper was also studied for comparison because of its better known behavior (ref. 4).

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EXPERIMENTAL PROCEDURE

Polycrystalline rods 6.35 mm in diameter and 125 mm in length, of 99.99 percent purity for Cu and Mo, and 99.95 percent purity for Nb were used for this investigation.

Before shock deformation, we annealed the samples 3 hours at 1150° C for Nb and 5 hours at 800° C for Mo, as we did previously (ref. 3). We annealed the copper samples 2 hours at 600° C (ref. 5).

For explosive deformation, the samples were clamped radially in a copper block (fig. 1); various impact distances were used in order to obtain different pressures on the samples. We chose oxygen free copper as a shock absorber because its motional impedence is similar to those of niobium and molybdenum and the curves of shock wave pressure versus impact distance are well known for this metal for the charge used (100 g of PLANP. We note that the spherical shape of the shock wave and the geometry of the sample will cause a nonuniform strain in the sample.

Internal friction measurements were made at about 15 kHz, between -190° C and 430° C, using longitudinal vibration and capacitive drive and detection (ref. 3). The strain amplitude was lower than 10^{-7}. The instrumental background was about 10^{-6}.

RESULTS

Copper

The internal friction spectra observed after explosive deformation at pressures of 22, 40, and 30 kbars (corresponding respectively to impact distances of 50, 40, and 30 mm) are shown in figure 2.

In the same figure, we show the internal friction corresponding to 10 percent room temperature tensile deformation at a strain rate of 0.01/minute.

After explosive deformation we can observe the Bordoni peak (P_0) and the Hasiguti peak (P_1) at the same temperature they appear after normal deformation: namely, -185° C and -45° C for P_0 and P_1, respectively.

The magnitudes of these two peaks are directly related to the pressure of the shock wave. The faster growth of the P_1 peak compared to P_0 can be attributed to the high temperature chosen for normalized annealing through its strong influence on P_1 (ref. 5).

The magnitude of these peaks compared to normal deformation,

$$\left(Q_{P_0}^{-1}\right)_{\epsilon=10\%} \simeq 2\left(Q_{P_0}^{-1}\right)_{80kbars}$$

and

$$\left(Q_{P_1}^{-1}\right)_{\epsilon=10\%} \simeq \left(Q_{P_1}^{-1}\right)_{80kbars}$$

indicates a high density of active dislocations after high speed deformation. However, the lack of precision inherent to the explosive deformation does not allow a more quantitative comparison.

Molybdenum and Niobium

Figure 3 shows the damping observed in molybdenum after shock deformation of 15, 30 and 50 kbars and after room temperature compression of 1 percent.

The low temperature peak grows monotonically with the pressure of the shock wave, and it appears at about the same temperature as the peak which appears after normal deformation, commonly referred to as the α peak (ref. 1). Its large value of $1.3\times10^{-3}(Q^{-1})$ for a pressure of 50 kbars can be directly related to the high density of dislocations produced by this deformation. In fact, a shock wave pressure of 80 kbars induced a radial rupture of the sample, as one might expect because of the thermodynamical analogy between low temperature normal deformation and room temperature high velocity deformation.

The high temperature "peaks" grow slower with shock wave pressure than does the low temperature one, and they seem to reach a saturation level with increasing shock wave pressure. The high temperature drop

4

off occurring around 320° C can be attributed to a pinning of dislocations by impurities, as we observe after normal deformation (ref. 3).

Like molybdenum, shock deformed niobium (fig. 4) shows a distinct low temperature peak which increases with shock wave pressure, and some high temperature "peaks" generally exhibiting the same general shape as normal deformation-induced peaks.

We clearly observe from these curves that the low temperature peak is 30 percent broader for shock wave deformation than for normal deformation, but it appears at nearly the same temperature.

The high temperature "peaks", on the other hand, exhibit a small shift after shock deformation toward lower temperatures. Again, as with molybdenum, we notice the high temperature drop of these peaks due to a pinning of dislocations by impurities, probably oxygen in this case (ref. 3).

If we compare the magnitude of the low and high temperature peaks after shock wave deformation and after normal deformation, we can observe that for nearly equal low temperature peaks, the corresponding high temperature "peaks" are twice as large after shock wave deformation than after normal deformation. We already noted (ref. 3) that the ratio of high temperature "peaks" intensity to low temperature peak intensity increase with decreasing temperature of normal deformation.

DEFORMATION

These studies on Mo and Nb lead to several observations regarding the internal friction spectrum induced by shock deformation:

- exactly the same damping peaks are observed after shock deformation and after normal deformation.

- the size of the shock induced peaks seems to indicate a large density of active dislocations.

- the magnitudes and ratios of the high and low temperature shock-induced peaks are similar to those observed after a large amount of low temperature normal deformation.

We would expect that the ratio of peak heights would vary throughout the deformation range (i.e., elastic or plastic), but we assume that in the shock

deformation considered here the deformation will always be in the plastic range.

Several interpretations have been previously proposed to explain the peaks observed in BCC metals after normal deformation (ref. 3). Specifically, we associated the low and high temperature peaks with kink formation on edge and screw dislocations respectively (the pinning overtaking the lattice effect at high temperature (refs. 3 and 6). In most cases, this interpretation agreed fairly well with our former results (ref. 3), but the influence of impurities and the fact that frequency dependence was not measured did not exclude another mechanism which corresponds to an impurity-dislocation interaction occurring just prior to the pinning of the dislocations by migrating impurities.

In the case of shock deformation we observe, particularly in niobium, that the ratio of the heights of the high temperature peak to the low temperature peak is twice that for room temperature normal deformation. Moreover, it has been observed by electron microscopy (ref. 7) that shock deformation induces a predominance of screw dislocations in this pressure range. Therefore, this behavior, similar to that observed after low temperature deformation, can be directly explained by the "screw-edge" interpretation.

The smaller effect observed in molybdenum may be associated with the interference of twins produced in great amount in this metal by high pressure shock deformation.

In the same way, the broader low temperature peak observed after shock deformation, especially in Nb, may correspond to a larger distribution of relaxation times due to the more complex dislocation structure resulting from the shock.

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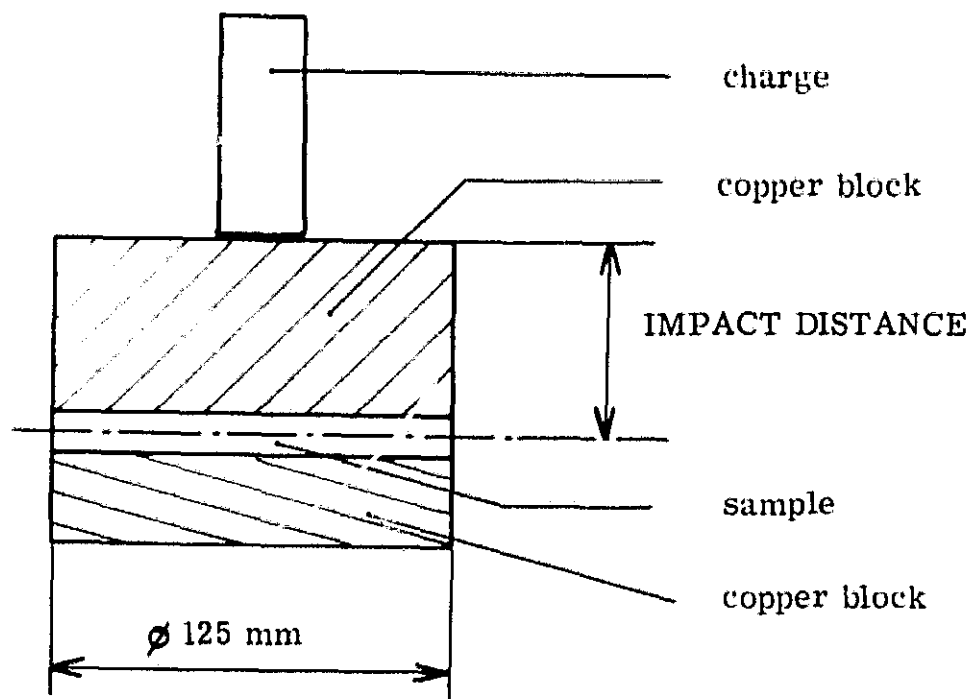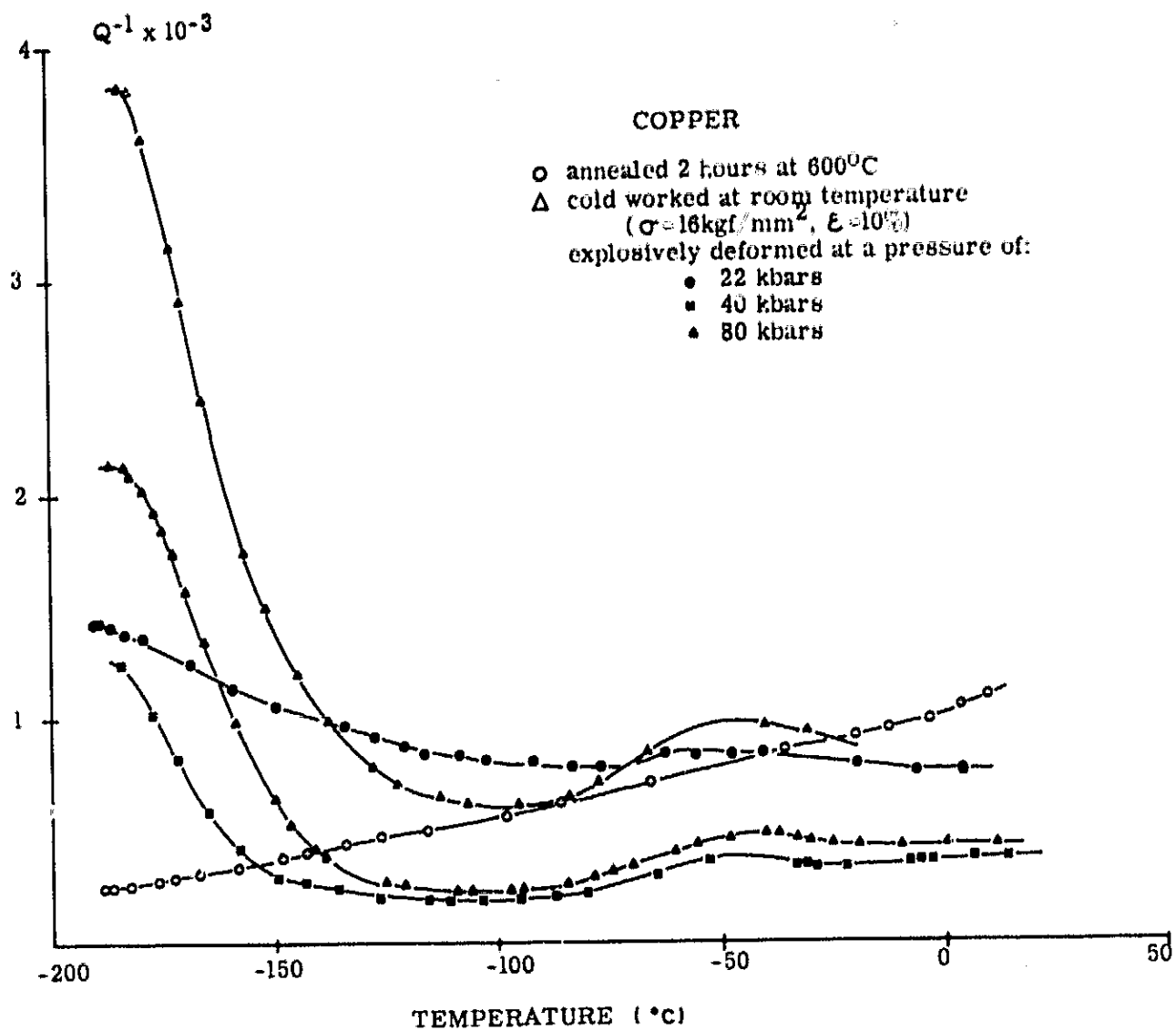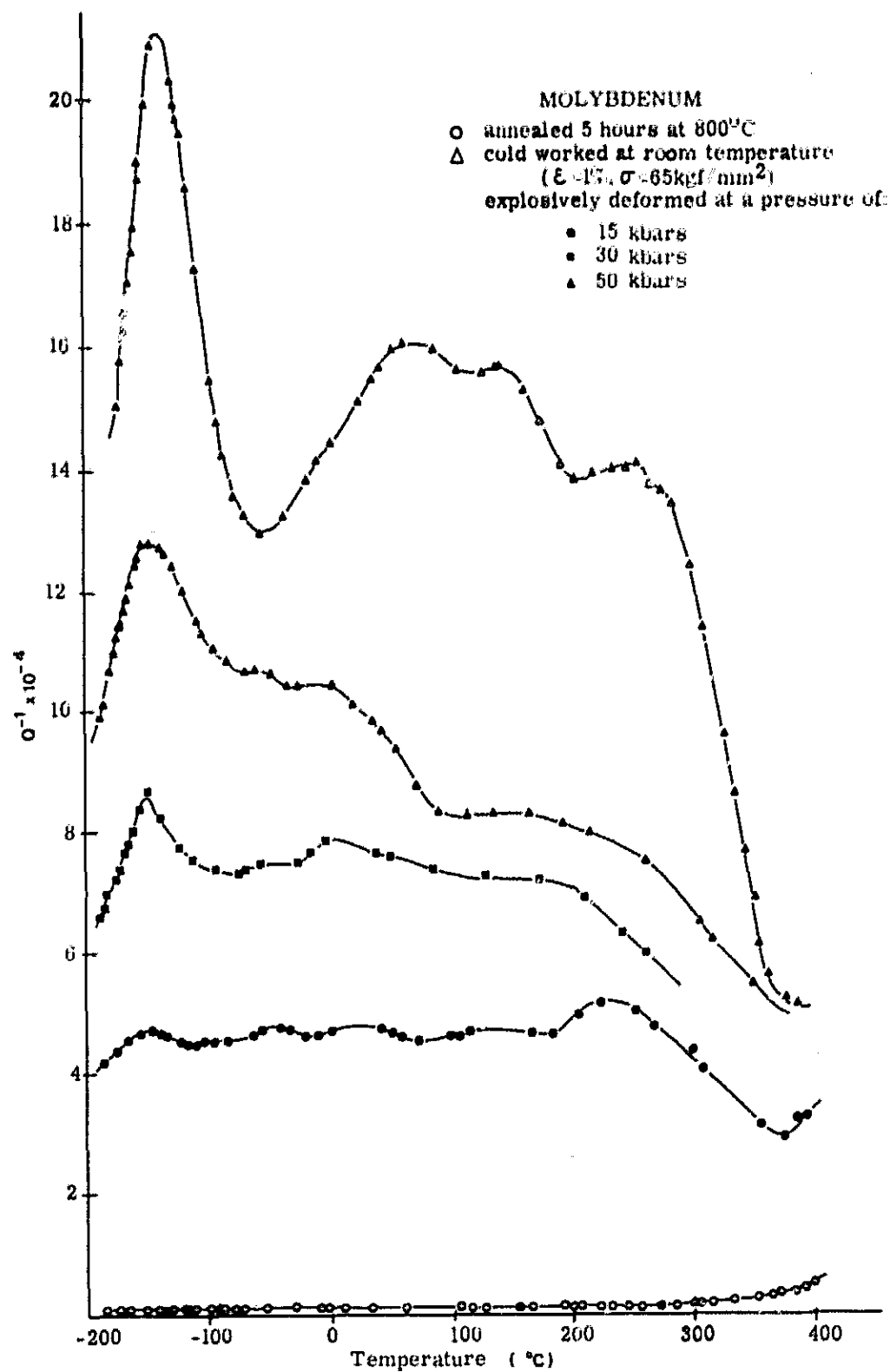
Figure 1: Sample holder for explosive
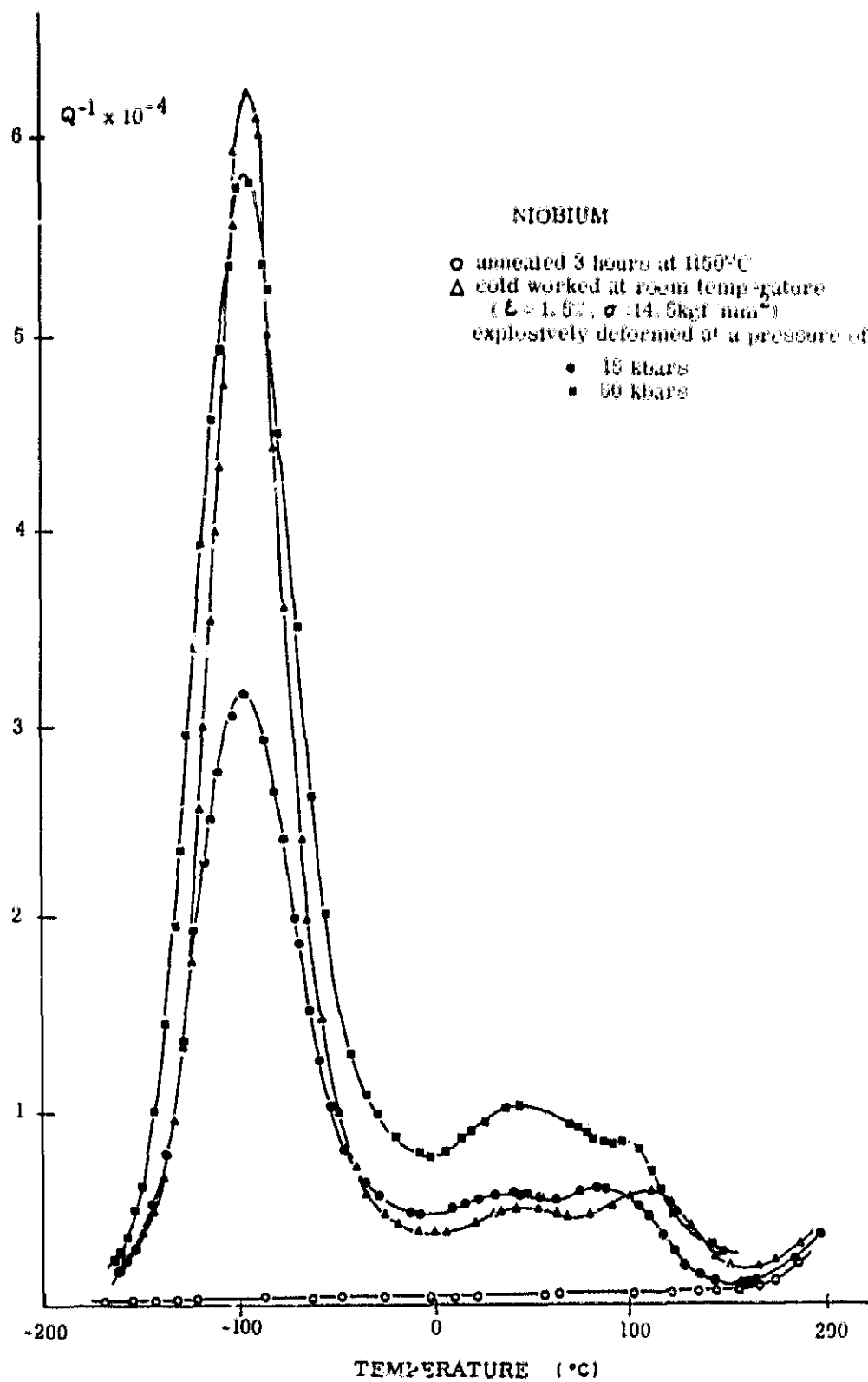deformation.

COPPER

o   annealed 2 hours at 600^0C
△   cold worked at room temperature
      ($\sigma = 16$kgf/mm^2, $\varepsilon = 10\%$)
      explosively deformed at a pressure of:
      ●   22 kbars
      ■   40 kbars
      ▲   80 kbars

TEMPERATURE (°C)

Figure 2

Figure 3

NIOBIUM

o annealed 3 hours at 1150°C
Δ cold worked at room temperature
    (ε = 1.6%, σ = 14.5kgf/mm²)
    explosively deformed at a pressure of:

    ● 18 kbars
    ■ 60 kbars

TEMPERATURE (°C)

Figure 4